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CHARACTERIZATION OF THE MK 1 MOD 0 SQUIB

Impedance Measurements in the Frequency Range 50-1500 Megacycles (U)

31 MAY 1960

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

CHARACTERIZATION OF THE MK 1 MOD 0 SQUIB

Impedance Measurements in the Frequency Range 50 - 1500 Megacycles

Prepared by:
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Approved by: [signature]
Chief, Explosion Dynamics Division

ABSTRACT: The impedance characteristics of the Mk 1 Mod 0 Squib were determined by the use of an admittance meter for the frequency range of 50 to 1500 megacycles. In general the reactance values obtained were very close to what could be expected if the squib were considered to be a symmetrical two-conductor parallel transmission line terminated with a 1-ohm resistor (the bridge wire). Under limited conditions of frequency and lead length the investigation showed that the squib could be considered to consist of lumped parameters: pure inductances for the leads within and without the bakelite portion of the plug and a pure resistance for the bridge wire.

PUBLISHED AUGUST 1960

* At Explosives Research and Development Establishment, Waltham Abbey, England.

This work was carried out while Dr. Wyatt was in residence at NOL as a visiting research scientist.

Explosions Research Department
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NavOrd Report 6826 31 May 1960

Dr. R. M. H. Wyatt of ERDE, Waltham Abbey, United Kingdom, was assigned to NOL for a period of two years as an exchange scientist. While at NOL he worked on various sensitivity problems associated with the ignition of explosives by electrical energy. The present work was done in connection with the characterization of the response of the Mk 1 Mod 0 Squib to different electrical energy wave forms. Of particular interest were problems associated with hazards from electromagnetic radiations such as might be propagated by communication equipment and radar. The high frequencies often associated with such radiations made desirable the study of the squib impedance at these frequencies.

This work was carried out under Task NOL-443, Hazards of Electromagnetic Radiation to Ordnance. The study bears on Explosives Research Key Problem 7.7.7 - Investigate the basic mechanism of initiation of explosives; develop new and more reliable tests for sensitivity - listed in NavOrd Report 3906.

W. D. COLEMAN
Captain, USN
Commander

C. J. Aronson

C. J. ARONSON
By direction

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INTRODUCTION

Under the Hero* program the Naval Ordnance Laboratory is determining the response characteristics of the Mk 1 Mod 0 Squib to various electrical pulses such as condenser discharge, constant current, constant voltage, radar, and electro-magnetic radiation received from CW communication equipment. In order to gain deeper insight into the factors which determine the extent of the squib's response to energy received at various frequencies, it would be helpful to know the impedance of the squib at the frequencies of interest. Of particular concern is the impedance at high frequency where inductance and capacitance contribute significantly to the overall impedance. To answer this need, measurements of the impedance of the Mk 1 Mod 0 Squib as a function of frequency for various conditions of lead length have been carried out. The results obtained are presented here interpreted in terms of transmission line theory.

THE MK 1 MOD 0 SQUIB

A sketch of the Mk 1 Mod 0 Squib is shown in Figure 1. The important features as far as its impedance is concerned are as follows:

(a) <u>The wire bridge</u>. The bridge wire is made of platinum-iridium alloy. The percentage of iridium is nominally 25%, but as long as the specifications for the resistance of the wire (180 - 225 ohms per foot) and the resistance of the bridge (1.0 ± 0.3 ohm) are satisfied, the percentage of iridium can be varied. It can be as low as 17% or as high as 35% (based on the variation of resistance with composition). The bridge diameter is 0.0010 ± 0.0002 inch.

* Hazards of Electromagnetic Radiation to Ordnance

(b) The plug. The plug is made of bakelite to the Military Specification MIL-P-14, Type MFH, mineral filled and heat resistant. At high frequencies the electrical properties of the bakelite may become increasingly important.

(c) The cup. The cup is made of gilding metal (95/5 brass) per Military Specification JAN-G-439. The side wall thickness is 0.008 inch, and the bottom thickness varies from approximately 0.0030 inch at the center, to 0.0040 inch at the edge. The length is approximately 0.450 inch.

(d) The lead wires. The leads are No. 24 or No. 22 solid round electrolytic, or certified oxygen free, copper wire, Military Specification JAN-W-538, pretinned or not pretinned. If not pretinned, the wire has a single coating of Formvar, Formex, or Polyvar. The insulation which extends 1.5 inches beyond the plug is of double wrapped celanese, plus one coat of cotton braid, lacquer coated, so that the outside diameter is 0.06 inch maximum. The lead wire diameter is 0.0201 inch (No. 24) or 0.0253 inch (No. 22) and the distance between centers in the plug is 0.0821 or 0.0853 inch.

(e) The explosive. The explosive filling is made up of two parts, an XC-9* charge immediately around the bridge wire, and the main charge of black powder. These two materials make a possible extra path between the bridge wire posts and to the cup.

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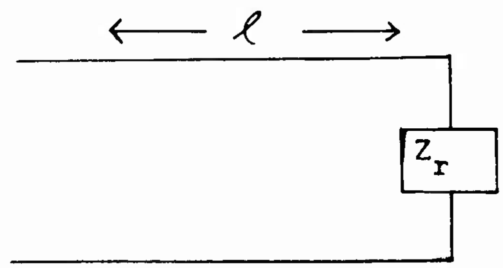
* NavOrd O.D. 6652, "Preparation of Diazodinitrophenol Ignition Mixture", describes this explosive charge.

THEORY

The squib (with its leads) may be considered to be similar to a balanced transmission line since it is a symmetrical assembly terminated in the wire bridge. The reactance of such a line is a tangential function of the lead length at constant frequency, or of the frequency at a constant lead length. For small reactances, the reactance of a given squib and lead length will be a linear function of frequency, and because of this it is possible that the squib can be represented by a simple lumped circuit.

It thus appeared desirable to consider the theory of transmission lines in order to see what sort of variation of reactance versus frequency would be obtained, and whether or not the squib would exhibit such a reactance.

Consider a two-wire line of length ℓ terminating in an impedance Z_r as shown below



The impedance looking into the line — the impedance as seen by the source — assuming zero losses is given by

$$Z = Z_o \frac{Z_r + jZ_o \tan\beta\ell}{Z_o + jZ_r \tan\beta\ell}, \qquad (1)$$

where Z_o is the characteristic impedance, j is $\sqrt{-1}$, and β is the phase constant per unit loop length of line.[1]

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(1) NavShips 900,038, Impedance and Admittance Diagram for Transmission Lines and Wave Guides.

When the terminating impedance Z_r is equal to the line impedance Z_o, Equation (1) reduces to

$$Z = Z_o , \tag{2}$$

i.e., the input impedance is independent of the line length. This implies that the line length is infinite, and this is the significance of the term "characteristic impedance" of the line. The characteristic impedance can be calculated from the physical dimensions, i.e., the lead wire diameter and separation, see Appendix A.

If the line is terminated in a short circuit, then Z_r is zero and Equation (1) reduces to

$$Z = jZ_o \tan \beta \ell . \tag{3}$$

Equation (3) shows that as the line length is increased the input impedance will follow a tangent-like relationship. This is shown in Figure 2 where the impedance is plotted against the electrical line length, $\beta \ell$, in wave length units of the input frequency, λ, (or in terms of the phase constant, where 1 wave length corresponds to a phase constant of 2π). For line lengths less than $\frac{\lambda}{4}$, the impedance is a pure inductive reactance increasing with increasing line length. At $\frac{\lambda}{4}$ the impedance is infinite and an apparent open circuit exists. This point is an anti-resonant point. As the line length is increased from $\frac{\lambda}{4}$ to $\frac{\lambda}{2}$ the impedance, which is a pure capacitive reactance, increases from minus infinity to zero. At $\frac{\lambda}{2}$, which is a resonant point, the impedance is zero and an apparent short circuit exists. For line lengths between $\frac{\lambda}{2}$ and λ the pattern is repeated. For a small region on either side of the zero reactance points, the curves are linear, i.e. wherever

$$\tan \frac{\beta}{m\pi} \ell \doteq \frac{\beta}{m\pi} \ell$$

for $(m-\frac{1}{2})\pi < \beta < (m+\frac{1}{2})\pi$.

Thus with a coaxial line or a no-loss two-wire line terminated in a short circuit, a determination of the variation of impedance with line length at a fixed frequency, would give anti-resonant points at $\ell = (2m+1)\frac{\lambda}{4}$ and resonant points at $\ell = \frac{m\lambda}{2}$.

Conversely, for a fixed line length and varying frequency, anti-resonant points and resonant points will be obtained at frequencies of $c/(2m+1)\frac{\lambda}{4}$ and $c/\frac{m\lambda}{2}$ respectively, where c represents transmission velocity.

For the particular case $\ell = \frac{\lambda}{8}$, and $Z_r = o$ (i.e., a short circuit)

$$Z = jZ_o . \tag{4}$$

This means that a short circuited line, $\frac{\lambda}{8}$, appears as a pure reactance, the magnitude of which is equal to the characteristic impedance.

METHOD OF MEASUREMENT AND APPARATUS

Whenever it is used the Mk 1 Mod 0 Squib always has several inches of lead wire as an integral part connected to the initiating source. Thus it is desirable to carry out measurements on the whole squib, i.e., the plug, cup, and lead wires. Consequently the aim should be to choose a method in which information is obtained on the effects of the lead wires on the one hand, and on the effects of the plug, bridge wire, and cup on the other. This can be accomplished usually by making measurements on squibs of differing lead lengths.

Both admittance and Q meters were available for making measurements. The admittance meter can be used to determine values of series resistance and series reactance over the range of frequency 50 to 1500 megacycles/second. Q meters can also measure series resistances and reactances in the range 1 to 200 megacycles/second. The admittance meter was used mainly because of its greater range of frequency and because there was at the time of the measurements particular interest in the 300 megacycles/second region.

A block diagram of the admittance meter and the associated equipment is shown in Figure 3. Figure 4 shows a photograph of the equipment.

The squibs were mounted perpendicularly to the face of the mount. One lead was attached to the central conductor and the other to the outer face such that the two leads were kept parallel and at a distance apart identical to the spacing within the plug as shown in Figure 5.

To cover the frequency range 50 to 1500 megacycles/second, pairs of oscillators were used. Their outputs were 50 to 250 megacycles/second, 250 to 900 megacycles/second, and 900 to 2,000 megacycyles/second, respectively. An outline of the adjustments for the impedance measurements is as follows[2]:

(a) Adjust the source oscillator to the desired frequency, say N megacycyles/second.

(b) Adjust the susceptance stub to correspond to this frequency. It is essential that this stub be calibrated according to the method in the instruction booklet.

(c) Adjust the local (detecting) oscillator so that a maximum deflection is obtained on the I.F. amplifier (approximately N + 30 or N -30 megacycyles.)

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2 - Operating Instructions for Type 1602-B General Radio Company Admittance Meter can be consulted for complete details.

(d) Attach the short circuit termination (Type 874-WN3) to the line, and adjust the length of the line to an odd number of greater quarter wave lengths (usually $\frac{5\lambda}{4}$, except if the frequency is too small, when $\frac{\lambda}{4}$ or $\frac{3\lambda}{4}$ is used, or if the frequency is too large, when $\frac{7\lambda}{4}$ or $\frac{9\lambda}{4}$ is used.) This is carried out by shortening or lengthening the line until a minimum deflection is obtained on the I.F. amplifier. Then lock the line.

(e) Replace the short circuit termination by the component mount to which the unknown is attached.

(f) Adjust the conductance, susceptance, and multiplying arms of the admittance meter until a minimum deflection is obtained. Note the readings on the three arms. If the conductance reading is G, the susceptance reading B, and the multiplying factor M, then the series resistance is 2.5 x G x M ohms, and the series reactance is 2.5 x B x M ohms.

It is essential that the polystyrene beads separating the inner and outer conductors of the coaxial line be checked frequently for dirt, cracks, and surface crazing. Dirt can be removed by cleaning the bead after dismantling the connector. If the bead is cracked or is badly crazed, it should be replaced.

EXPERIMENTS AND RESULTS

(a) Coaxial Line. The apparatus and the method of operating it was checked by determining the impedance of a coaxial terminating unit which was fitted directly to the component mount as shown in Figure 6. The results obtained are of interest here since they show how well the experiments follow the theory. The characteristic impedance, see Appendix A , of this extension piece (90 ohms) was not quite the same as that of the General Radio apparatus for measuring the impedance (50 ohms), but was sufficiently similar so that the anti-resonant and resonant points would not be affected. Figure 7 shows how the reactance varied as the frequency was increased from 0 to 400 megacycyles/second. The similarity between this reactance and the first branch of Figure 2 is immediately apparent. The unit was 14.14 cm long.

The first anti-resonant point occurred at 510 megacycles/second and the first resonant point at 1,020 megacycles/second. The second anti-resonant point is estimated to be 1,500 megacycles/second. These observations can be summarized as follows:

Point	Frequency (megacycles/ second)	Wave Length (cm)	Fractional Wave Length (cm)
1st anti-resonant	510	58.8	$\lambda/4 = 14.7$
1st resonant	1020	29.4	$\lambda/2 = 14.7$
2nd anti-resonant	1500	20.0	$3\lambda/4 = 15.0$

These are in the precise order predicted by theory, and the appropriate fractional wave lengths are equal in magnitude to the line length. Moreover, at a frequency corresponding to $\frac{\lambda}{8}$, the reactance is 87 ohms, in good agreement with the value for the characteristic impedance given above.

A similar experiment with a shorter coaxial terminating unit (7.07 cm long, characteristic impedance 83 ohms) gave a first anti-resonant frequency of 1,000 megacycles/second corresponding to a 30.0 cm wavelength, whence $\frac{\lambda}{4} = 7.50$ cm. At 530 megacycles/second, i.e., a length of $\frac{\lambda}{8}$, the reactance was 87 ohms in excellent agreement with the characteristic impedance. The results were not affected by the presence or absence of a shield such as is normally fitted to the component mount. The reactance measurements obtained for frequencies up to 700 megacycles/second are also shown in Figure 7.

(b) Double-Rod (Two-Wire Line). A two-wire line, terminated in a short circuit, was made up of two 1/8-inch diameter rods — one being fitted into the central conductor, and the other into one of the threaded holes of the component mount as shown in Figure 8. The distance between centers was 31/64 inch giving a characteristic impedance of 245 ohms, see Appendix A. These two rods were terminated on the lid of the shield. The line length of this arrangement was 9.90 cm. The reactance and resistance observed for this line are shown in Figure 9. The first anti-resonant point occurred at a frequency of 700 megacycles/second. The corresponding wave length for this frequency is 42.9 cm which gives $\frac{\lambda}{4} = 10.7$ cm. Conversely, a 9.90-cm line length should give a first anti-resonant point at a frequency corresponding to a wave length of four times 9.90 cm, i.e., 760 megacycles/second. The first resonant point occurred at a frequency of 1,515 megacycles/second for which the wave length is 19.8 cm whence $\frac{\lambda}{2} = 9.90$ cm.

Another experiment, using a similar arrangement with a line length of 5.66 cm, gave a first anti-resonant point at a frequency of 1,250 megacycles/second. The expected value was 1,320 megacycles/second. Thus the experiments for this type of line also gave results closely approximating predictions of the theory.

If the short circuit termination is not made coincident with the lid of the shield, but is placed some distance inside, then different values of reactance and resistance as functions of frequency are obtained. For a line length of 5.71 cm (actually the same two rods as in the last case) the first anti-resonant point was at 620 megacycles/second, the second was at 1,430 megacycles/second, with the first resonant point at 970 megacycles/second as shown in Figure 10. This shift in the anti-resonant and resonant points is due to the difference in the magnetic field pattern in the two cases. This results in an increase in the capacitive contribution, causing the capacitive reactive portion of the impedance to become dominant at lower frequencies. This means that the first anti-resonant and the resonant points occur at smaller frequencies, and the second anti-resonant point occurs at a frequency between the first and second anti-resonant frequencies of the ideal case. Also these new frequencies are no longer in the ratio 1 : 2 : 3 etc.

(c) Mk 1 Mod 0 Squibs. Squibs with straight parallel leads can be mounted in two ways:

(1) With one lead connected to the central conductor, and the other to the face of the component mount covered by a shield of appropriate size.

(2) As in (1) but with a shield of a size such that the cup of the squib is making contact with the lid of the shield.

The first way is similar to the second case of the two-rod assembly (i.e., terminated internally); and the second way is similar to the first case (i.e., terminated in the plane of the shield lid) except that there is a discontinuity in the electrical circuit in that the bakelite plug and explosive filling is interposed between the wire leads and the cup.

Most of the measurements on the Mk 1 Mod 0 Squib have been carried out with the first arrangement. Its characteristic impedance, assuming the leads are kept parallel (the distance apart being equal to the separation of the leads in the bakelite plug) is 230 ohms, see Appendix A. Figure 11 shows the results obtained for a squib with the distance from the mount face to the bridge wire 5.47 cm. The similarity between Figure 10 and Figure 11, i.e., for a double rod assembly and a squib of about the same length, is quite apparent.

Figure 12 shows the results obtained with a squib of 1.90-cm lead length, i.e., the distance from the component mount to the plane of the bridge wire. The first anti-resonant point occurs at a frequency of 1500 to 1600 megacycles/second, a value somewhat lower than would be predicted for the indicated lead length. This is because of the internal termination of the system. It is also noted that up to 900 megacycles/second the reactance increases linearly at approximately 14 ohms per 100 megacycles/second. The resistance rises very slowly from 1 ohm at low frequencies to 3 ohms at 500 megacycles/second and 7 ohms at 900 megacycles/second.

The impedance of squibs of other lead lengths were measured and the linear portion of the reactance curves compared. The range of frequency over which this linear portion occurred decreased as the lead length was increased. Table 1 shows how the reactance varied with frequency for squibs of lead length ranging from 1.0 cm to 10.3 cm. When the values of the reactances at frequencies of 50, 100, and 200 megacycles/second are plotted against lead length, as shown in Figure 13, straight lines are obtained for lead lengths up to 9 cm. The reactances for a lead length of 10.3 cm fall below the lines. This is probably due to the difficulty in keeping the long leads parallel and at the correct distance apart, especially as the squib is fixed horizontally to the mount.

Table 1

Reactance of Mk 1 Mod 0 Squibs as a Function of Frequency and Lead Length

Frequency (megacycles/second)	Reactance (ohms) Lead Length (cm) 1.0	1.90	3.10	4.07	5.5	7.0	8.7	10.3
50	5.5	7.5	9.2	13	15	18.7	22	24.5
100	8	12	19	22	30	39	44	47
200	16.7	24	39	45	60	76	93	102
300	25	41	58	78	106	145	179	280
400	32.5	54	80	104				
500	38.5	65	116					
600	--	85.5	162					
700	56	94						
800	--	116						
900	73	124						
1000	--	144						
1100	89							

Note: The impedance varies linearly with the frequency above the horizontal lines.

The slopes of the lines shown in Figure 13 are directly proportional to the frequency. The reactance follows the relationship:

$$X = (0.0468\ell + 0.050)f \text{ ohms} \tag{5}$$

where ℓ is the lead length in cms, and f is the frequency in megacycles/second. With the shorter leads, the linear dependence of reactance upon frequency is maintained up to larger values of frequency. The frequency range over which the relationship is linear is shown also in Table 1 by the values included above the solid line. Figure 14 shows graphically the relationship between reactance and frequency at various lead lengths. The results are summarized as follows:

Lead Length (cm)	Reactance (ohms)	Upper Frequency Limit (megacycles/second)
1.90	$X = 0.139f$	900
3.10	$X = 0.195f$	400
4.07	$X = 0.204f$	250
9.0	$X = 0.471f$	200

where f is the frequency in megacycles/second.

If we assume that the squib, over these particular frequency-lead length conditions, can be represented by a lumped circuit involving three items:

(a) An inductance due to the lead wires, L_1,

(b) An inductance associated with the plug and bridge wire, L_2,

(c) A resistance due to the bridge wire, R,

then the reactance of the squib is

$$X = 2\pi f\, L_1 + 2\pi f\, L_2. \tag{6}$$

Comparing this with Equation (5),

$$L_1 = \frac{0.0468}{2\pi}\ell \quad \text{and} \quad L_2 = \frac{0.050}{2\pi}$$

i.e., $L_1 = 0.00746\ell$ microhenries and $L_2 = 0.00796$ microhenries. Rounding off the figures, the lumped circuit is then an inductance of $(0.0075\ell + 0.008)$ microhenries in series with R, the 1-ohm resistance of the bridge. The impedance is then represented by

$$Z = j\,(0.0075\ell + 0.008)f + 1.0. \qquad (7)$$

(d) <u>Comparison of Observed Inductance with That Due to a Two-Wire Line</u>. It is of interest to compare the observed inductance with that calculated for a two-wire line of the same dimensions as the squib. When the distance between the center of two wires is D cm, and the wire diameter is d cm, the inductance is given by

$$L = 0.004\ell \cdot \ln\left(\frac{2D}{d}\right) - \frac{D}{\ell} + \mu\delta \text{ microhenries,} \qquad (8)$$

where ℓ is the length of the leads, μ is the permeability equal to unity, and δ is a term whose value depends on the frequency. Here δ is less than 0.01 for frequencies of 100 megacycles and above, so the third term can be neglected.[3]

For the Mk 1 Mod 0 Squib,

$$L = 0.004\ell\left[1.92 - \frac{0.22}{\ell}\right] \text{ microhenries.} \qquad (9)$$

When $\ell = 8$ cm $L = 0.061$ microhenries;
when $\ell = 1$ cm $L = 0.0068$ microhenries.

The inductances as calculated from the model (i.e., the contribution due to L_1) are 0.068 microhenries and 0.0075 microhenries respectively. Thus there is good agreement between the experimental and calculated values of the inductance due to a two-wire line.

(e) <u>Impedance Values for the Squib with Shortest Possible Leads</u>. The reactance values in Table 1 for the squib of 1.0-cm lead length do not fit the model. The values at 50 and 100 megacycles/second, however, are close to those predicted by the model. When all the values are plotted, they show that the reactance increases linearly with frequency up to 1100 megacycles/second, see Figure 15. However, the slope of the line is somewhat less than that for the model; 0.081 as compared with 0.0968. It was thought that the proximity of the cup to the face of the component mount was causing a reduction in reactance, but tests with

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3 - Handbook of Chemistry and Physics, 32nd edition, p.2685, Chemical Rubber Publishing Co.

an unloaded squib (i.e., no cup or ferrule) showed that there was no such effect. The reason for deviation from the model is not known at this time.

(f) Impedance of the Plug Alone. To gain an insight into the electrical properties of the bakelite plug, an unloaded squib with no bridge wire was studied. Actually, this squib was one which had been fired so that the base of the cup had been blown off. The remains of the bridge were removed. Figure 16 shows its impedance curve (the length of lead being the shortest possible, i.e., 1 cm.). As expected, the resistance and reactance at low frequencies were large, the latter being capacitive. At 600 megacycles/second the resistance had fallen to 14 ohms, and the reactance to -200 ohms. As the frequency was increased, the resistance remained fairly constant around 10 ohms, the actual values dropping from 14 at 600 megacycles/second to 8 at 1500 megacycles/second. Over the same range the reactance rose from -200 to -100 ohms at a constant rate. Assuming that the reactance continues to rise at a linear rate, it is estimated that it should equal zero at 2300 megacycles/second.

CONCLUSIONS

From these experiments it is concluded that with frequencies up to 300 megacycles/second the Mk 1 Mod 0 Squib having lead lengths between 1.9 and 9.0 cm can be considered to consist of a fixed inductance (due to the bakelite portion of the plug), an inductance proportional to the length of lead outside the plug, and a 1-ohm resistance (the bridge wire) arranged in series as a two-wire symmetrical parallel transmission line. Impedance of the squib can be calculated from transmission line theory. Over the range cited the reactance can be expressed as:

$$X = (0.0468\ell + 0.050)f. \tag{10}$$

Outside the cited range, but dependent on frequency and lead length, the expression may still be valid. It holds to higher frequencies at the shorter lead lengths.

APPENDIX A

Characteristic Impedances of Coaxial and Two Wire Lines

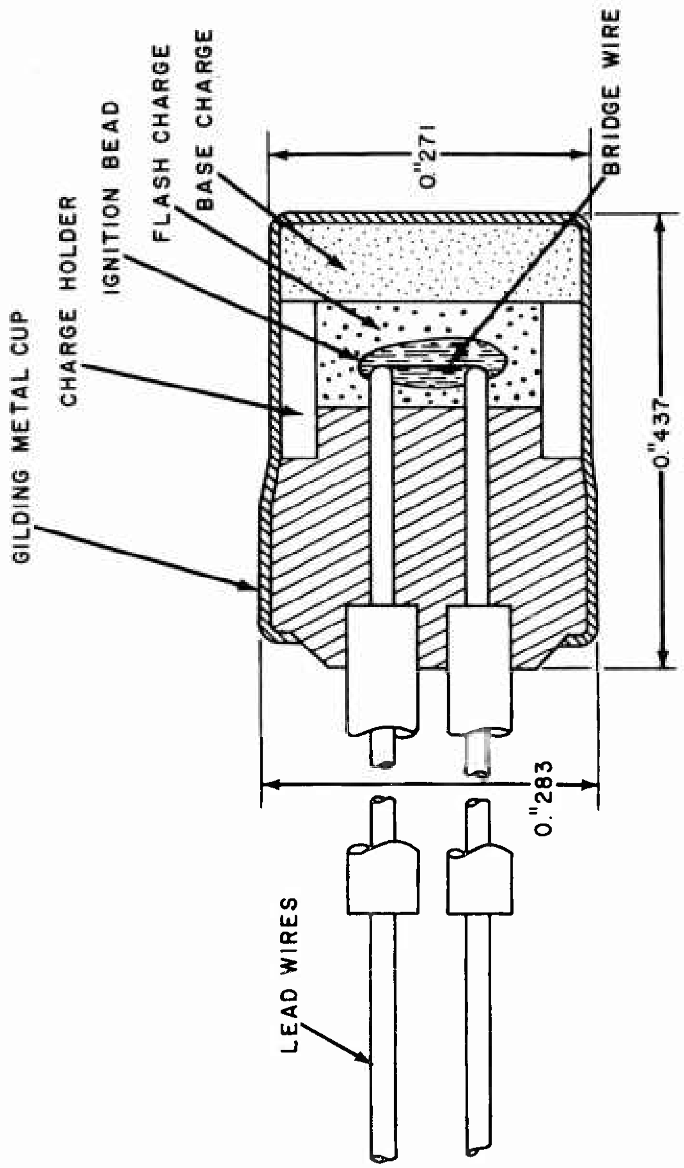
For a coaxial line, with a central conductor of radius a, and the outer conductor of radius b, the characteristic impedance is given by

$$Z_o = 138 \log_{10} \frac{b}{a} .$$

In the case of the long coaxial extension studied, b = 9/32" and a = 1/16", whence Z_o = 90 ohms. For the short extension, b = 1/4" and a = 1/6", whence Z_o = 83 ohms. For a two-wire line, with a wire radius of a, and a distance apart of D, the characteristic impedance is given by

$$Z_o = 276 \log_{10} \frac{D}{a} .$$

In the case of the two rod arrangement, a = $\frac{1}{16}$", and D = 31/64", whence Z_o = 245 ohms.
In the case of the MK 1 Mod 0 Squib, D = 0.085" and a = 0.0125". This gives a value of 230 ohms for its characteristic impedance. (The insulating material around part of the wire has been ignored.)



IGNITION BEAD - APPROX 5 mg DDNP/$KClO_3$
FLASH CHARGE - APPROX 45 mg BLACK POWDER
BASE CHARGE - APPROX 45 mg BLACK POWDER
BRIDGE WIRE - 0."001 PLATINUM-IRIDIUM
0."060 LONG

FIG. 1 SQUIB MK 1 MOD 0

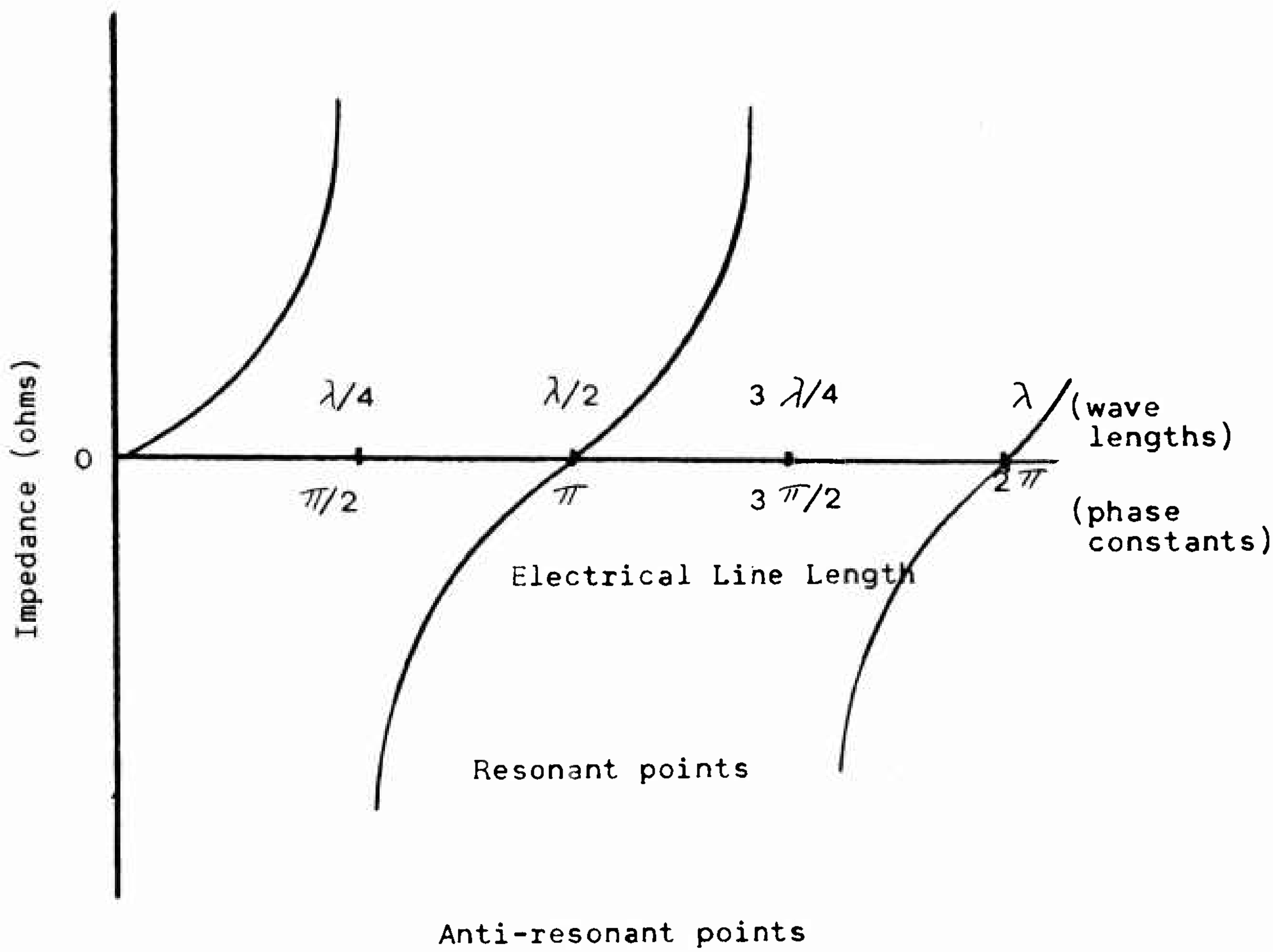


Figure 2. Impedance of a Two-Wire Short Circuited Transmission Line as a Function of the Line Length.

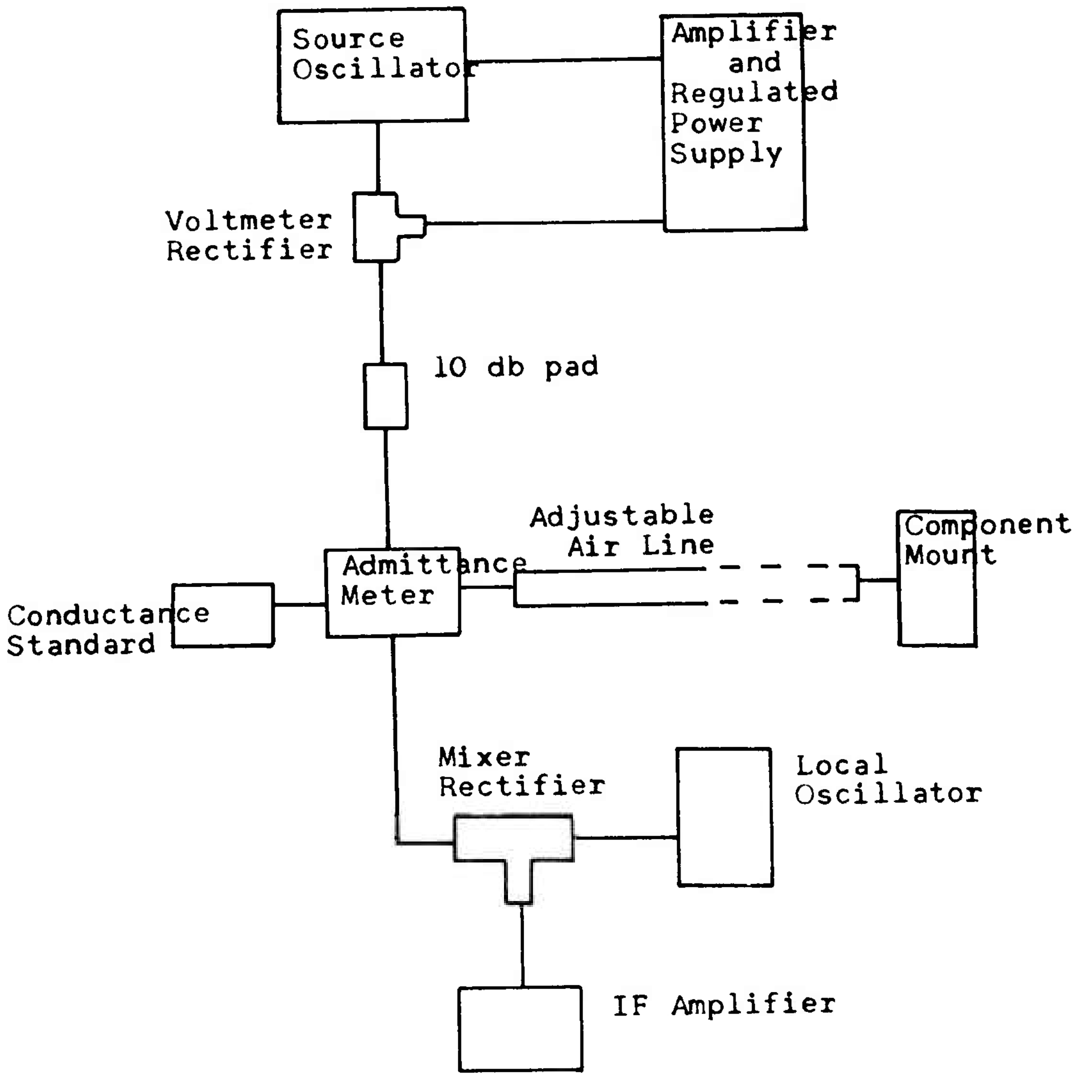


Figure 3. Block Diagram of Admittance Meter

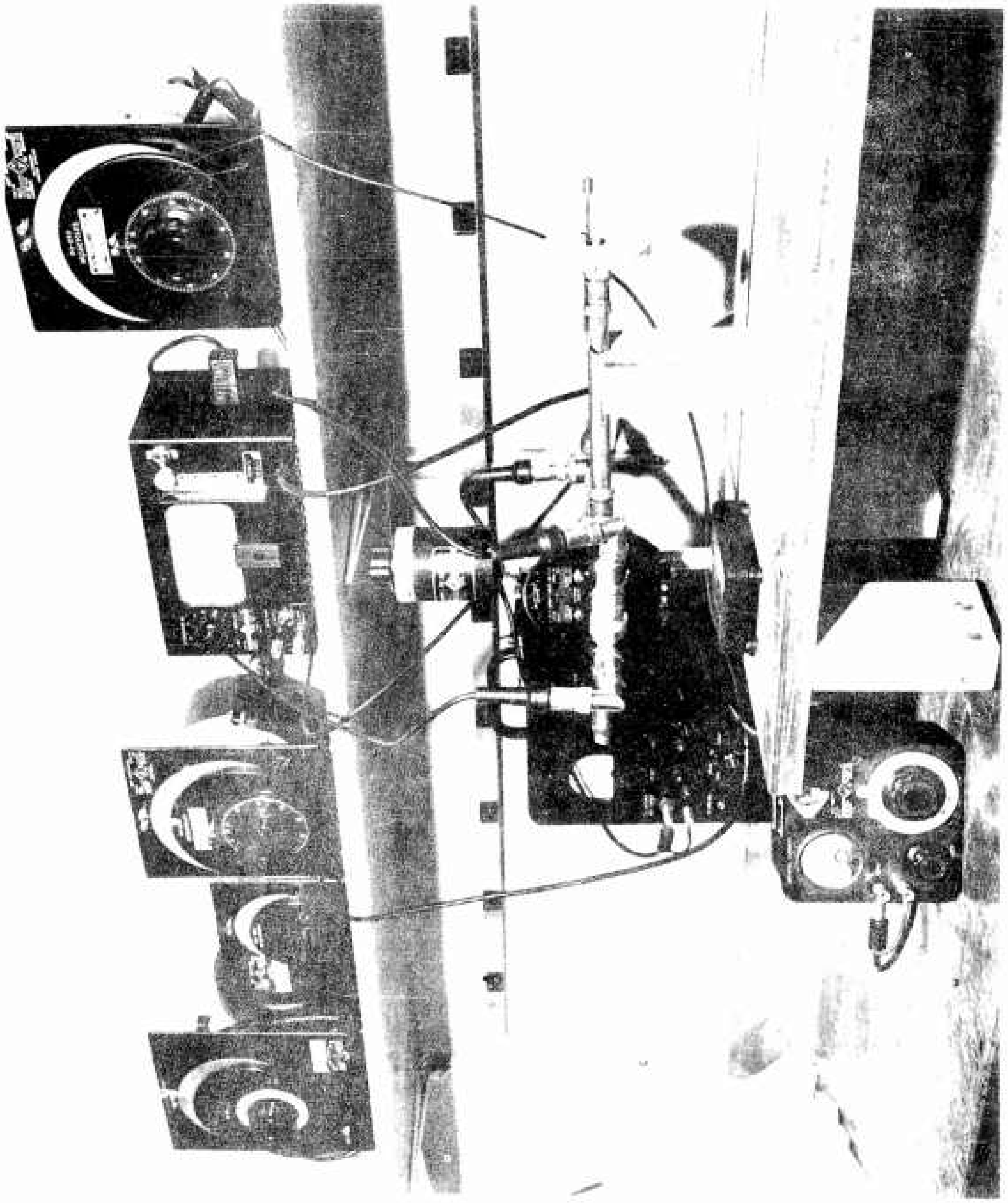


FIG. 4 PHOTO OF ADMITTANCE METER AND ASSOCIATED EQUIPMENT

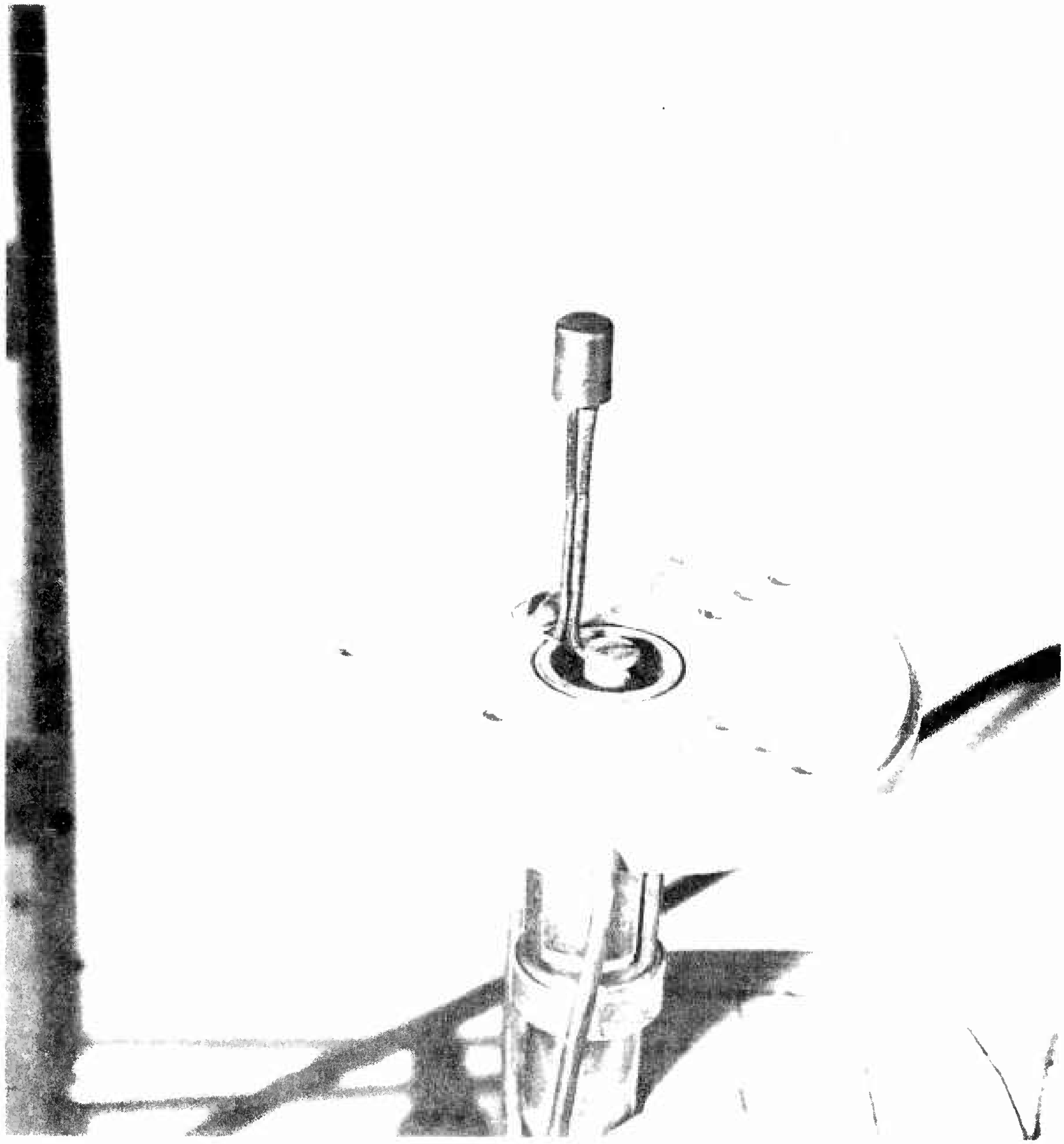


FIG 5 METHOD OF ATTACHING THE SQUIB TO THE MOUNT

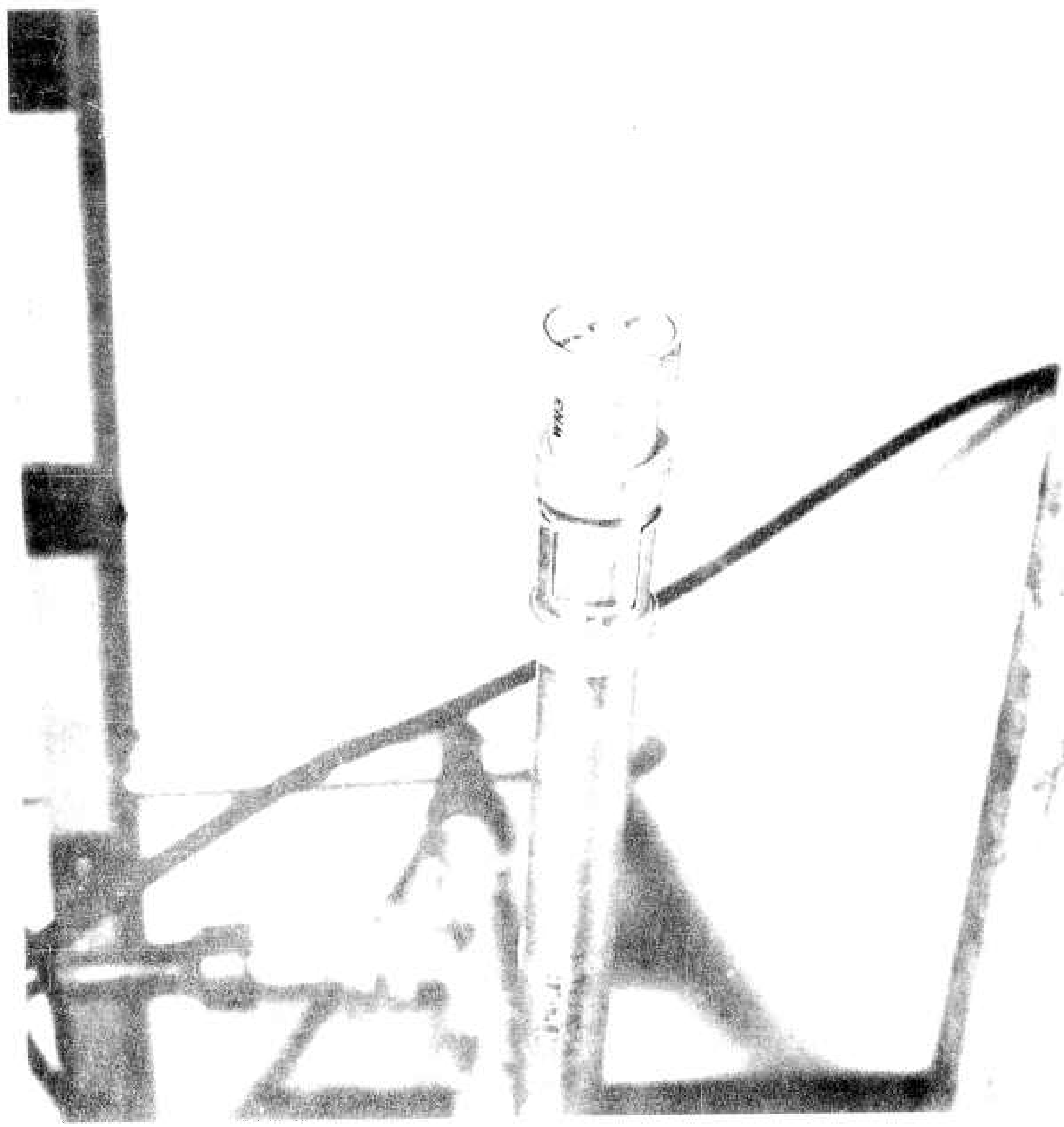


FIG. 6 COAXIAL TERMINATION

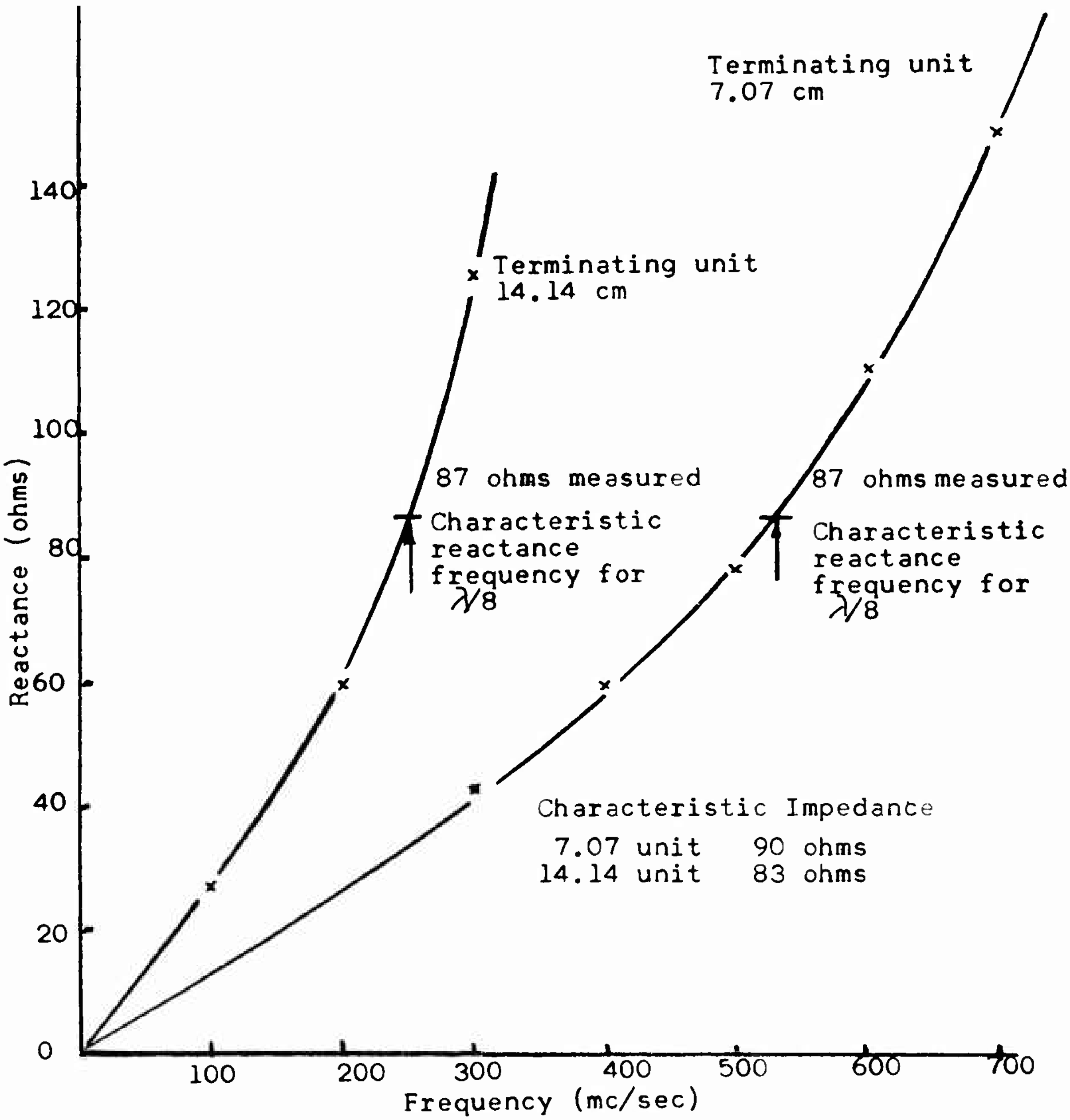


Figure 7. The Reactance of Terminating Units of Different Lengths as a Function of Frequency.

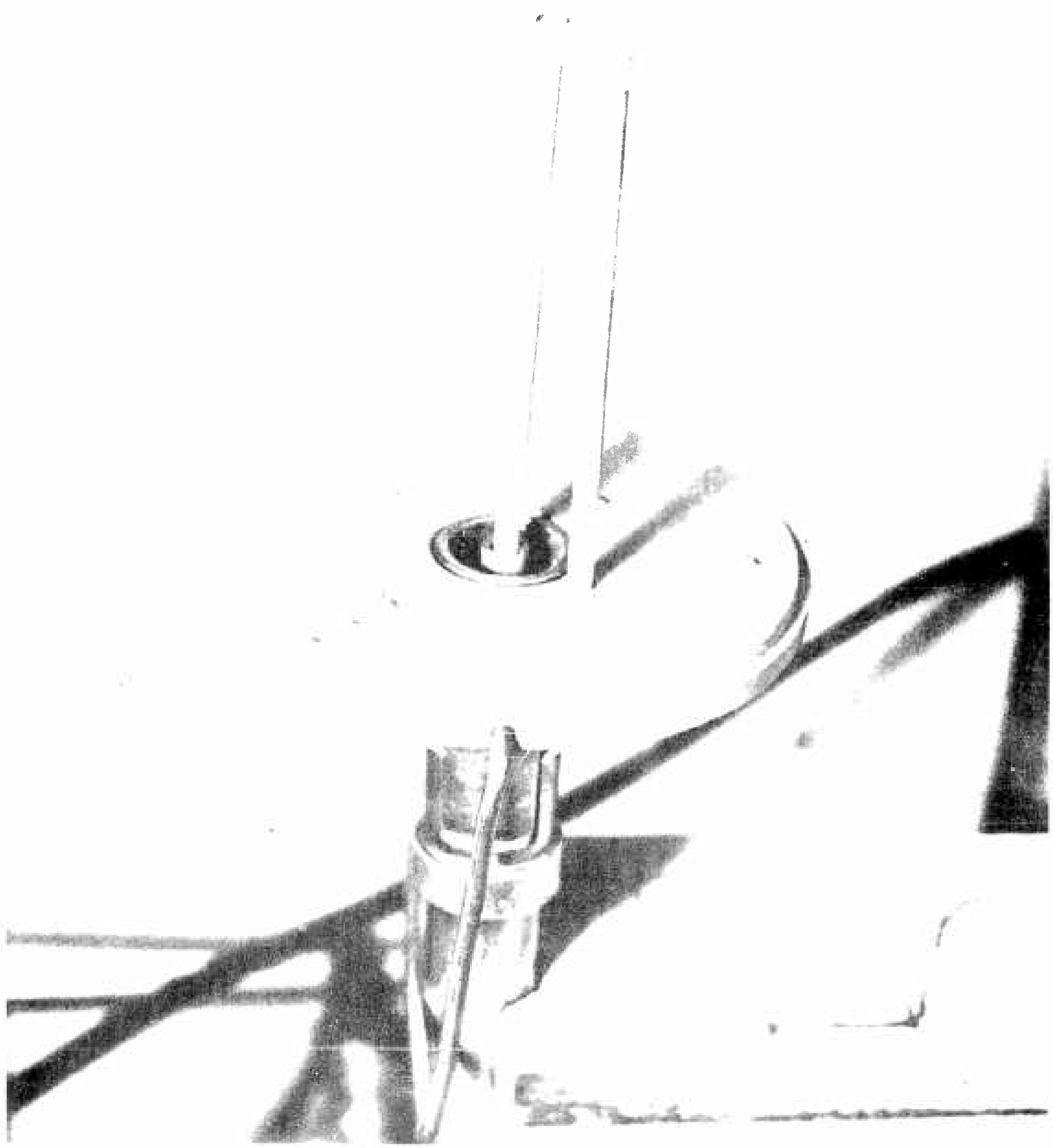


FIG 8 DOUBLE-ROD SHORT CIRCUITED LINE

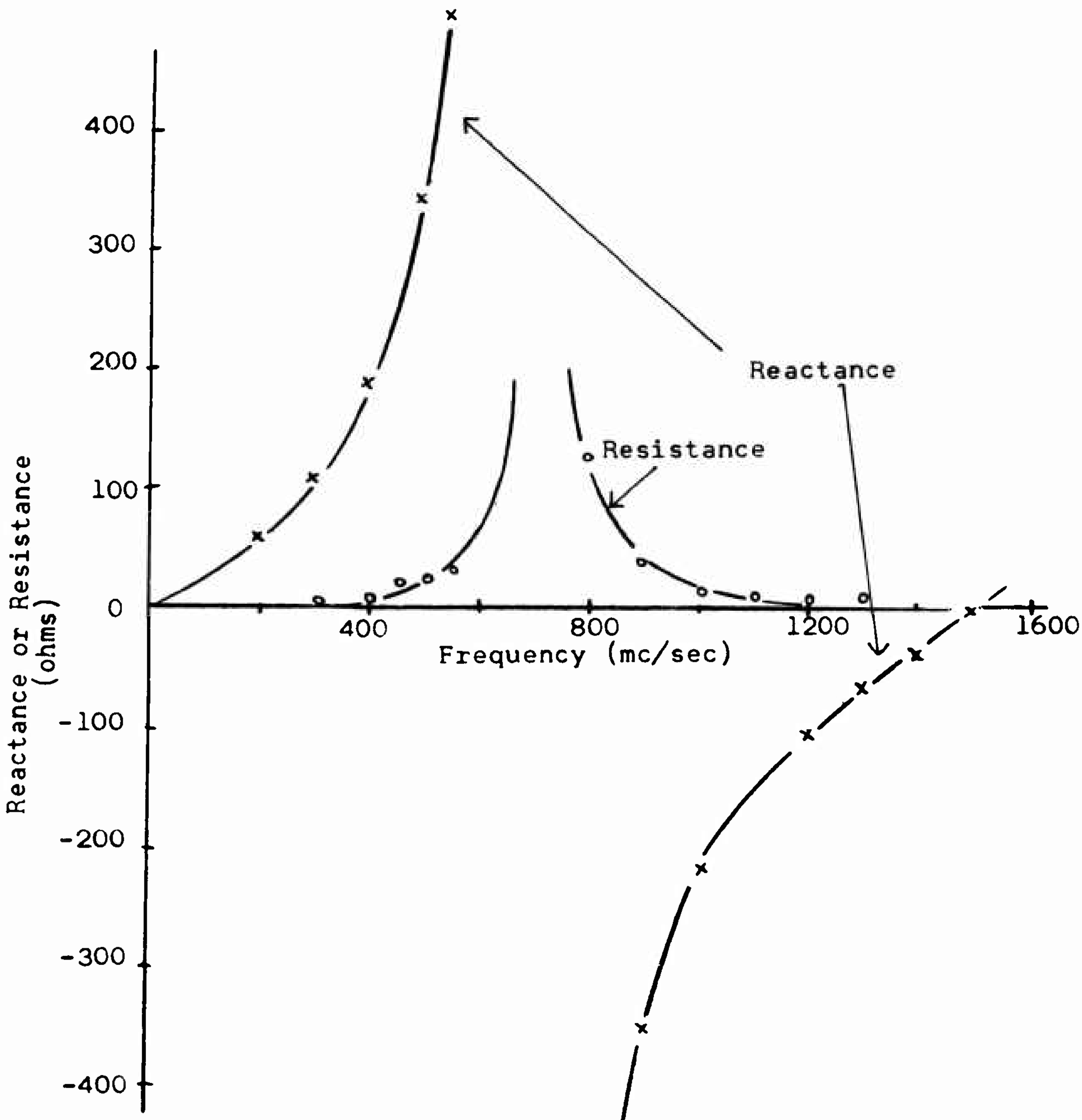


Figure 9. The Reactance and Resistance of a Double Rod Terminated in a Short Circuit as a Function of Frequency. Rod length 9.90 cm connected at lid of shield. Characteristic impedance is 245 ohms.

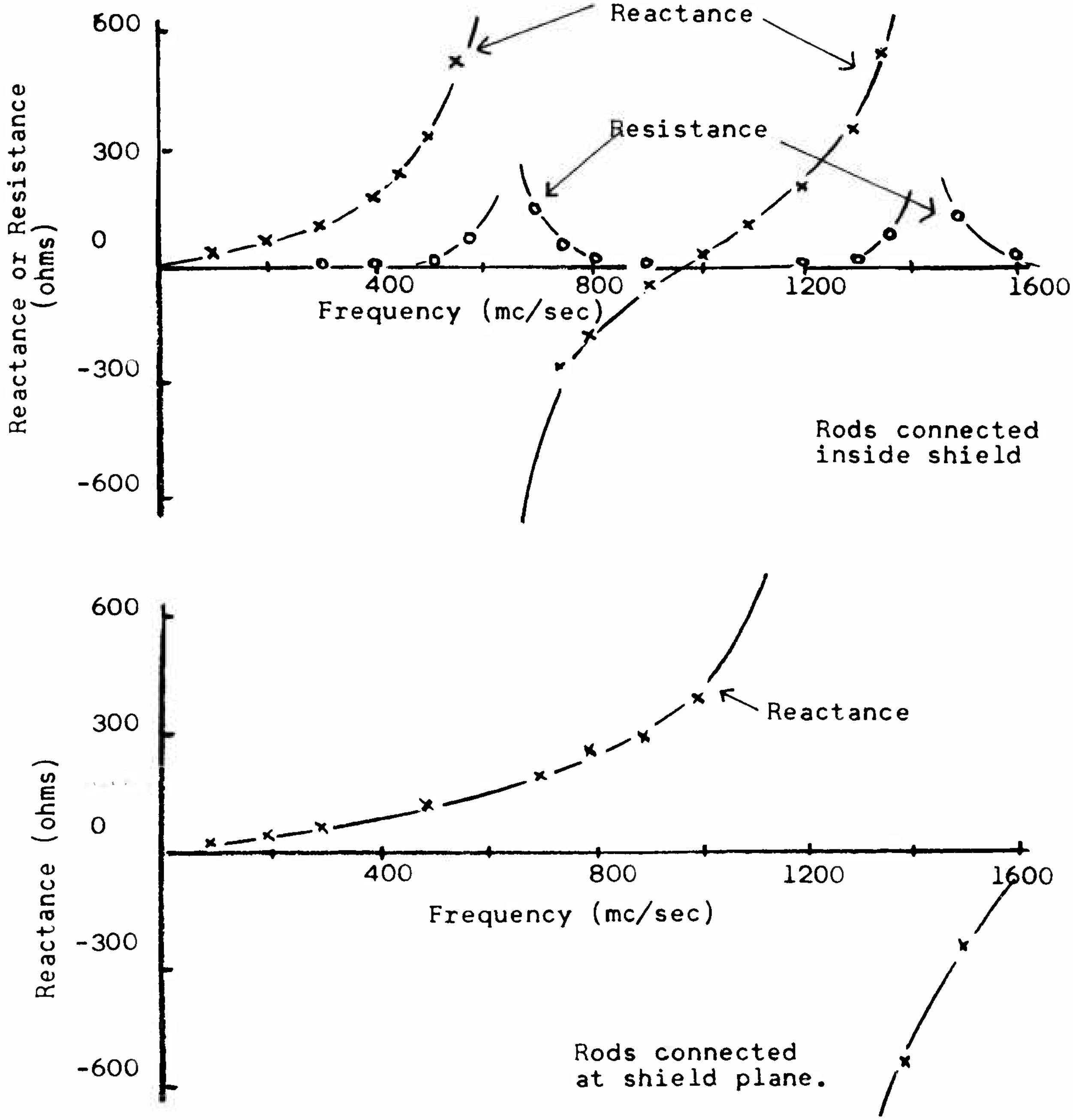


Figure 10. The Reactance and Resistance of a Double Rod Terminated in a Short Circuit as a Function of Frequency. Rod length 5.71 cm.

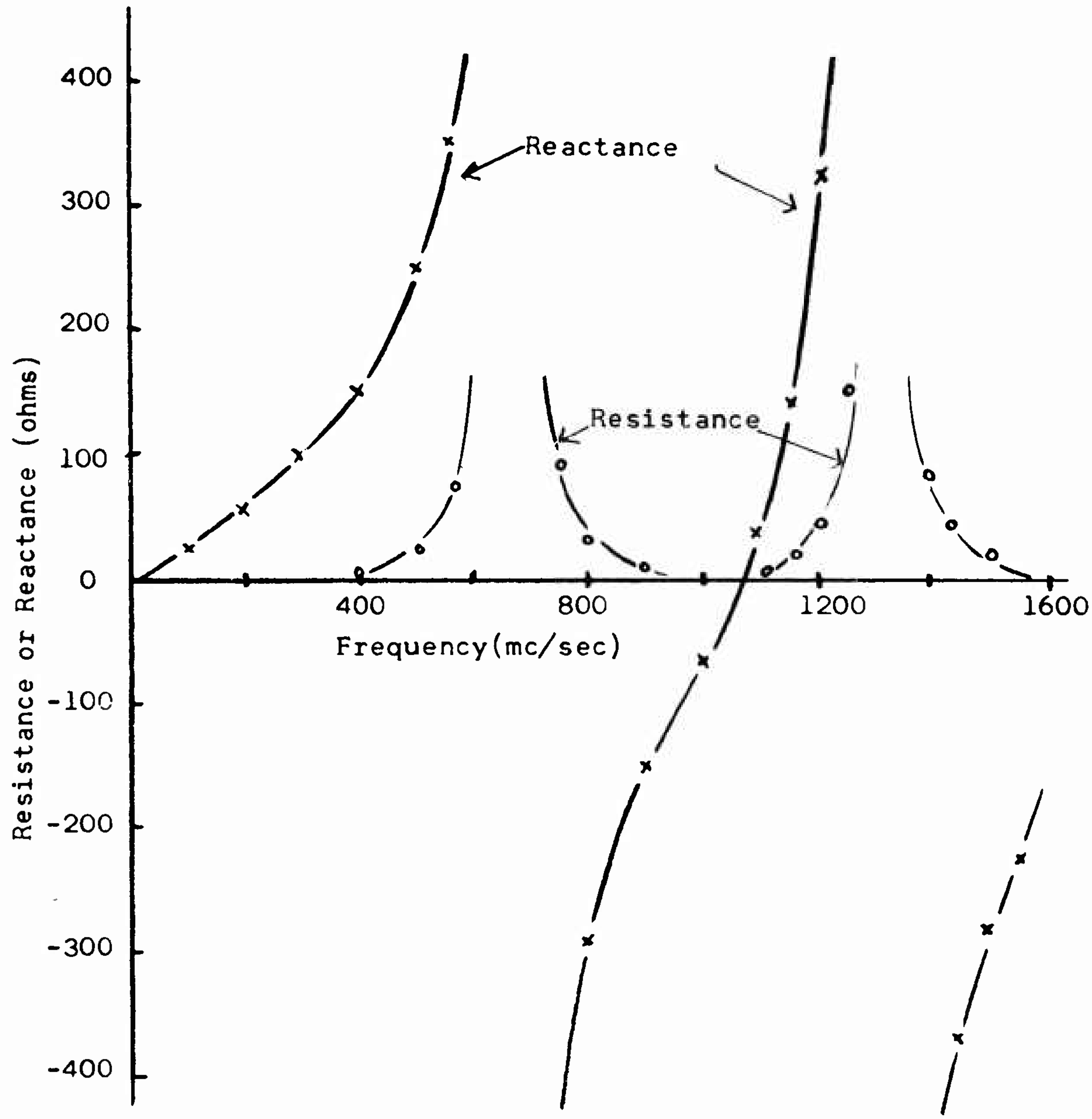


Figure 11. The Reactance and Resistance of a Mk 1 Mod 0 Squib as a Function of Frequency with a Lead Length of 5.47 cm.

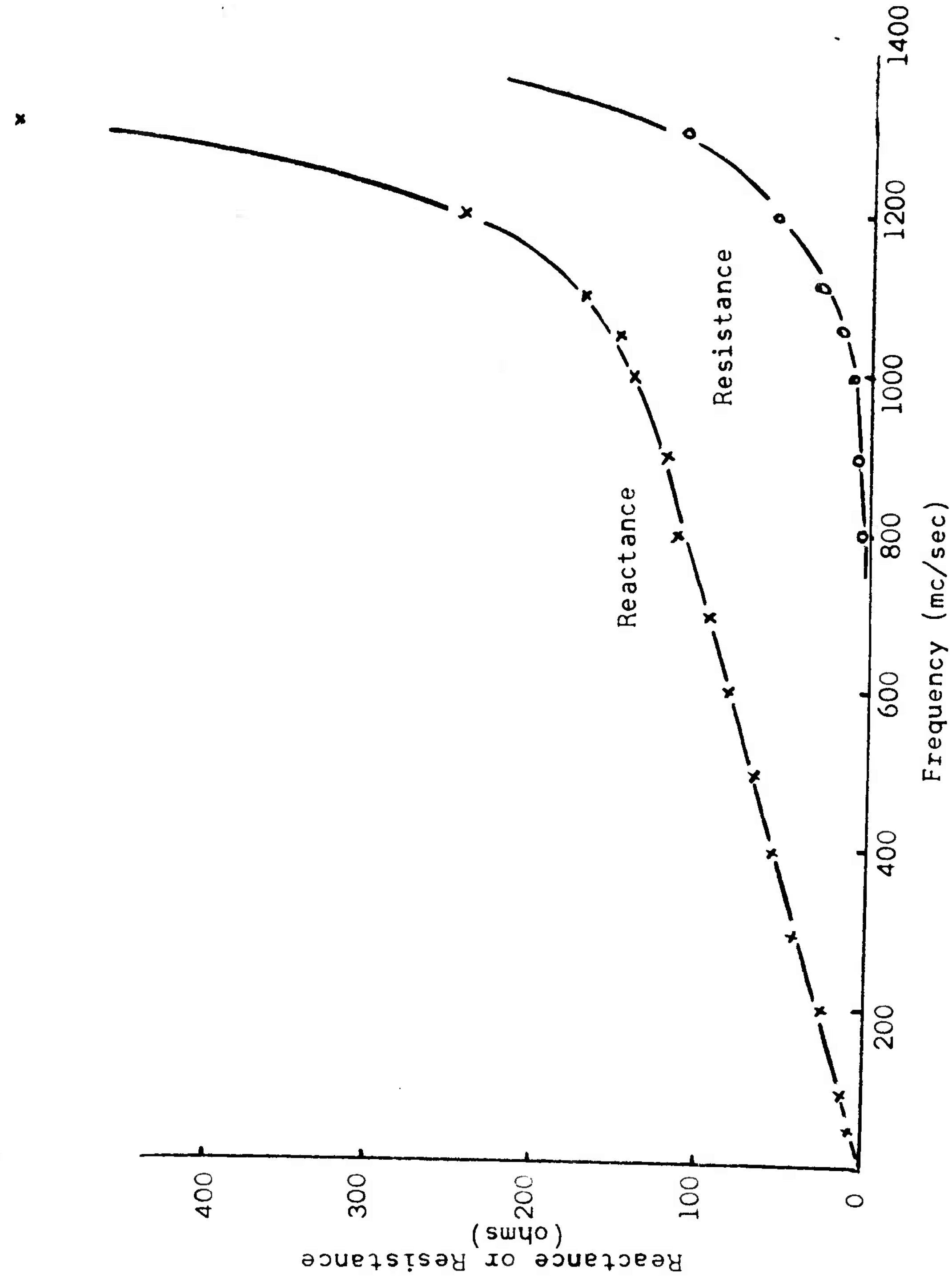


Figure 12. The Reactance and Resistance of the Mk 1 Mod 0 Squib as a Function of Frequency with Lead Length of 1.90 cm. The first anti-resonant point occurs at 1500 to 1600 megacycles per second.

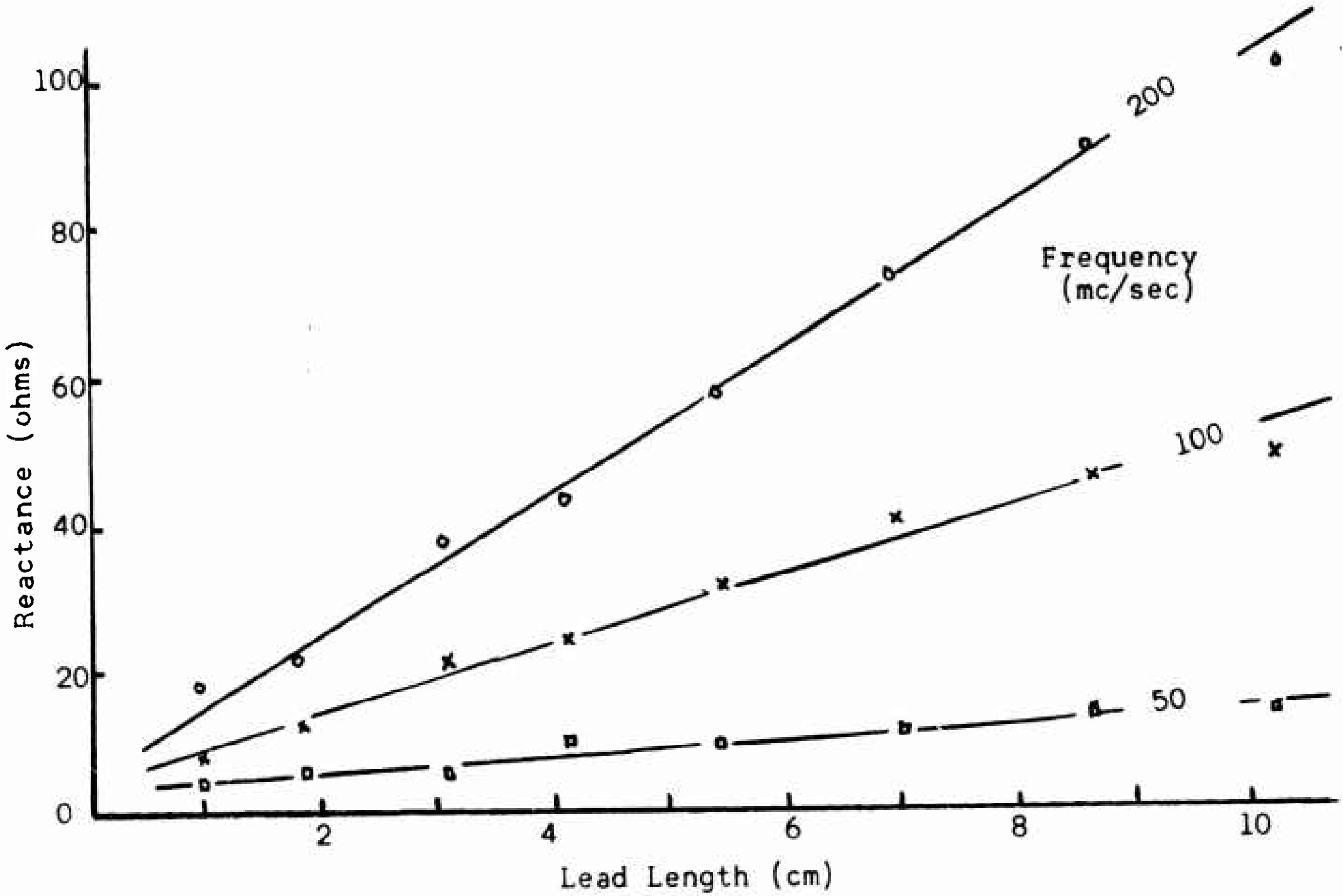


Figure 13. The Reactance of the Mk 1 Mod 0 Squib as a Function of Lead Length for Differenct Frequencies.

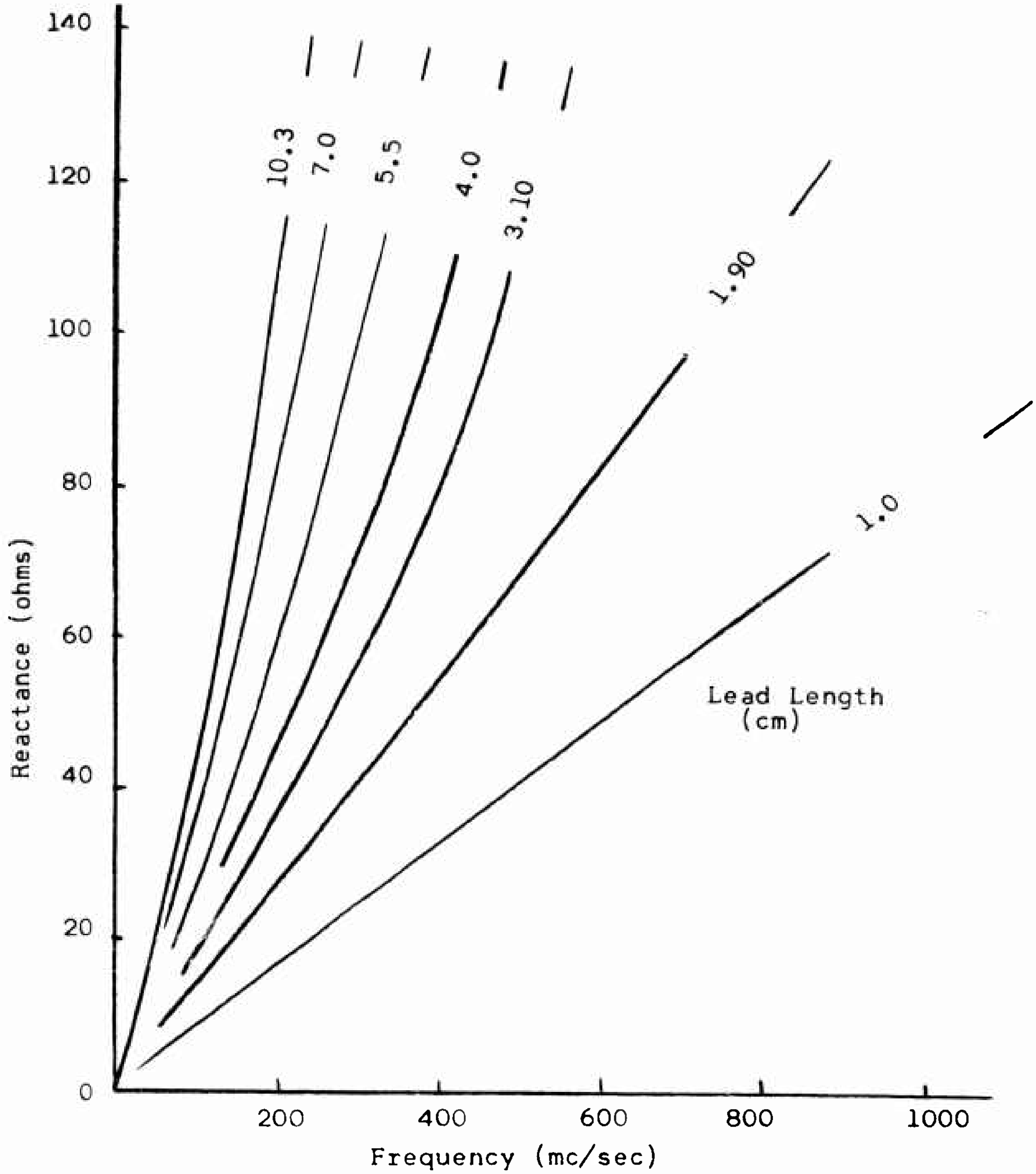


Figure 14. The Reactance of the Mk 1 Mod 0 Squib as a Function of Frequency for Various Lengths of Lead.

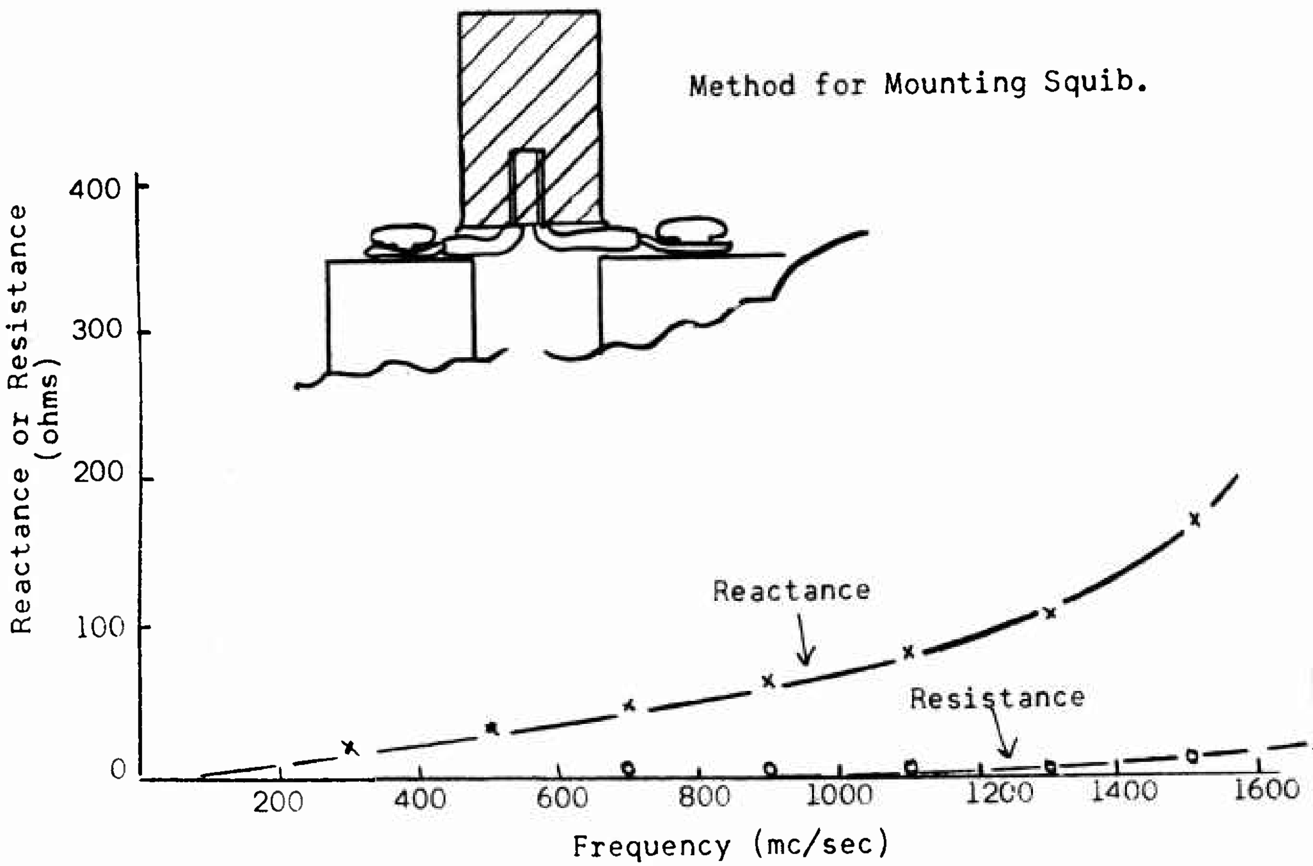


Figure 15. The Reactance and Resistance as Functions of Frequency of the Mk 1 Mod 0 Squib with Shortest Possible Leads. Lead length 1.0 cm.

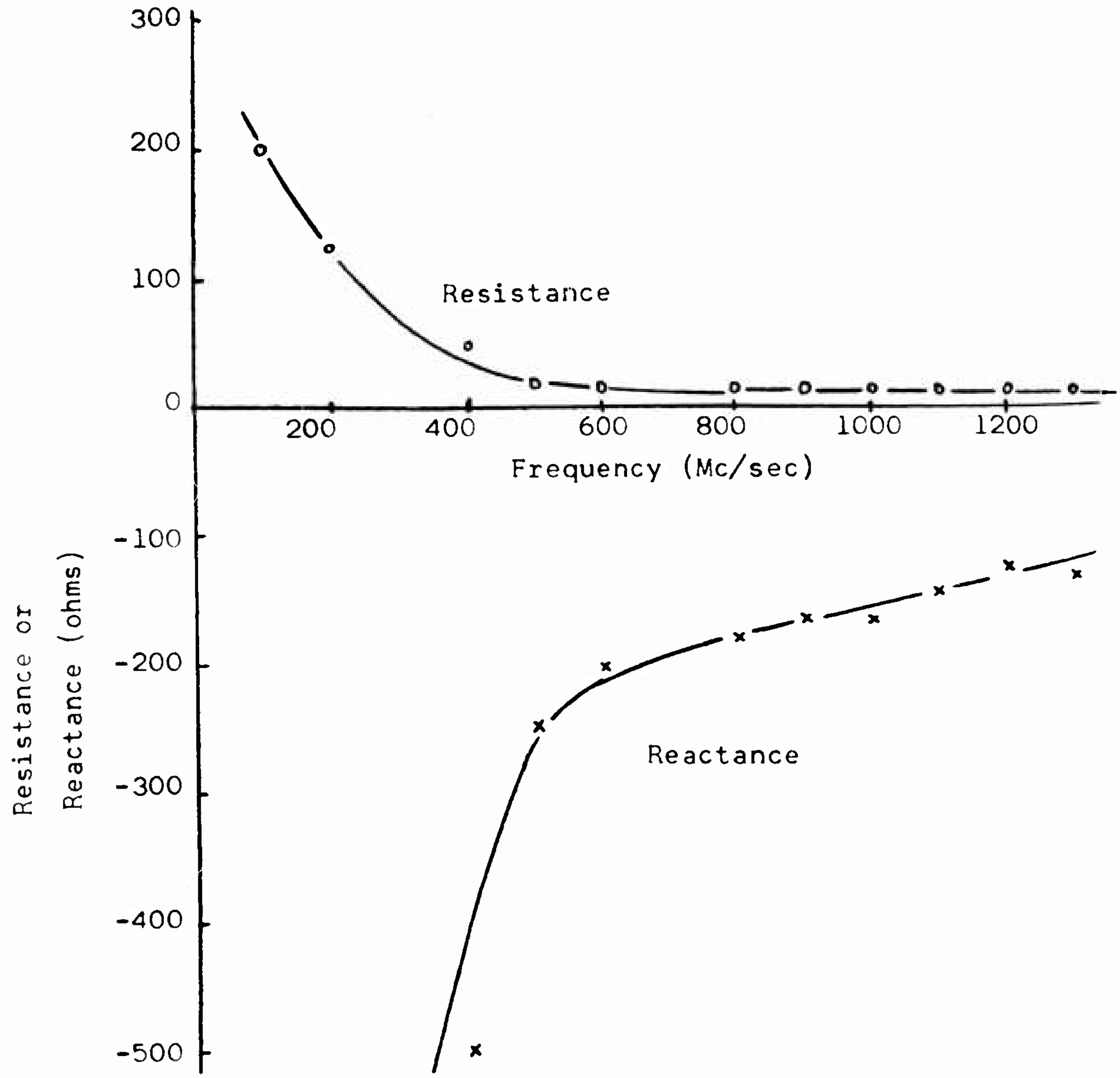


Figure 16. The Resistance and Reactance as Functions of Frequency of the Bakelite Plug Without Bridge Wire of the Mk 1 Mod 0 Squib. The shortest possible leads were used.